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대한영상의학회지

Comparison of ^{18}F-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography, Hydro-Stomach Computed Tomography, and Their Combination for Detecting Primary Gastric Cancer[1]

위암의 원발 병소 발견에서 ^{18}F-Fluorodeoxyglucose 양전자전산화단층촬영, 위장전산화단층촬영, 병용 검사의 유용성 비교[1]

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Purpose: To retrospectively compare the diagnostic accuracy for detecting primary gastric cancer on positron emission tomography/computed tomography (PET/CT) and hydro-stomach CT (S-CT) and determine whether the combination of the two techniques improves diagnostic performance.

Materials and Methods: A total of 253 patients with pathologically proven primary gastric cancer underwent PET/CT and S-CT for the preoperative evaluation. Two radiologists independently reviewed the three sets (PET/CT set, S-CT set, and the combined set) of PET/CT and S-CT in a random order. They graded the likelihood for the presence of primary gastric cancer based on a 4-point scale. The diagnostic accuracy of the PET/CT set, the S-CT set, and the combined set were determined by the area under the alternative-free receiver operating characteristic curve, and sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated.

Results: Diagnostic accuracy, sensitivity, and NPV for detecting all gastric cancers and early gastric cancers (EGCs) were significantly higher with the combined set than those with the PET/CT and S-CT sets. Specificity and PPV were significantly higher with the PET/CT set than those with the combined and S-CT set for detecting all gastric cancers and EGCs.

Conclusion: The combination of PET/CT and S-CT is more accurate than S-CT alone, particularly for detecting EGCs.

Index terms
Gastric Cancer
Stomach CT
^{18}F-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography
Detection
Combination

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INTRODUCTION

Gastric cancer is the fourth most common cancer worldwide (1) with a particularly high incidence in Asia (2). To reduce mortality from gastric cancer, it is essential to choose an optimal therapeutic approach, which depends on early detection and accurate preoperative staging.

Computed tomography (CT) has been the modality of choice for preoperative evaluation and staging patients with gastric cancer. Multidetector row CT (MDCT) with thin collimation offers near-isotropic imaging of the stomach and provides high quality multiplanar reformation. Dynamic contrast material-enhanced CT offers superior differentiation of tumor tissue from normal mucosa with adequate distention of the stomach using water as a negative contrast agent (3). However, CT plays only a limited role detecting lesions in patients with early gastric cancer (EGC) (1, 4).

^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography (^{18}F-FDG PET/CT) is a useful diagnostic technique in clinical oncology. ^{18}F-FDG PET/CT is highly accurate for determining resectability and detecting distant metastatic disease at the time of initial diagnosis. Various levels of FDG uptake have been found during primary tumor detection. Mucinous carcinoma and signet ring-cell carcinoma tend to show significantly lower FDG uptake than that of other histologic types of gastric cancer (5). The success rate of detecting EGC using ^{18}F-FDG PET is < 50%, but detection rates of 62–98% have been reported, depending on the histological characteristics of the advanced gastric cancer (AGC) (6). However, no studies have addressed the use of combined hydro-stomach CT (S-CT) and ^{18}F-FDG PET/CT to detect gastric cancer.

Therefore, the aim of this study was to retrospectively compare the diagnostic accuracy of S-CT with ^{18}F-FDG PET/CT for detecting primary gastric cancer and to determine whether the combination of the two techniques improves diagnostic performance.

MATERIALS AND METHODS

Patients

This retrospective study was approved by our Institutional Review Board, and informed consent was waived. A total of 329 patients were pathologically confirmed with gastric cancer in our hospital from December 2009 to November 2012 and underwent S-CT.

Of the 329 patients, 76 were excluded from analysis for one of the following reasons: 1) only underwent S-CT without ^{18}F-FDG PET/CT scanning (n = 20); 2) post-endoscopic submucosal dissection (ESD) status (n = 43); and 3) post-endoscopic clipping status or improper gastric distention (n = 13). After excluding these 76 patients, the final study group comprised 253 patients (age range, 35–86 years; mean age, 64.6 years; 176 men, age range, 35–86 years; mean age, 64.5 years and 77 women, age range, 38–86 years; mean age, 64.6 years).

Proof of Tumor Burden

Pathological proof of all lesions was obtained after ESD or surgery, which included ESD (n = 45), subtotal gastrectomy (n = 174), or total gastrectomy (n = 34). All 253 patients had a total of 267 confirmed adenocarcinomas (well-differentiated, 37; well- to moderately-differentiated, 5; moderately differentiated, 139; moderate to poorly differentiated, 19; poorly differentiated, 67). The specimens were histopathologically analyzed for depth of gastric wall invasion. Of the 267 lesions, 116 were classified as T1a, 63 as T1b, 26 as T2, 33 as T3, and 29 as T4a, according to the pathological TNM staging system developed by the 7th American Joint Committee on Cancer and the International Union Against Cancer (7).

CT Protocol

S-CT images were obtained from two scanners: a 64-channel CT scanner (Aquilion 64; Toshiba Medical Systems Co., Tokyo, Japan) in 232 patients, and a 128-channel CT scanner (Somatom Definition Flash; Siemens Medical Systems, Forchheim, Germany) in 21 patients. The following scanning parameters were used for the 64-MDCT scanner: collimation, 64 × 0.5 mm; pitch, 0.828; and rotation time, 0.6 second; and for the 128-MDCT: collimation, 128 × 0.625 mm; pitch, 0.8; rotation time, 0.5 second. The kilovoltage (kV) and effective tube current-time charge (mAs) were 120 kV and 200–250 mAs, respectively.

In our study, 500–1000 mL tap water was administered as an oral contrast medium to each patient immediately before CT to distend the stomach. Each patient had fasted for > 6 hours, and had received a 2 mL/kg intravenous dose (total volume, < 150 mL; 3 mL/sec) of nonionic contrast material (Ultravist 300; Schering, Berlin, Germany) through an 18-G angiographic catheter inserted in a forearm vein using an automatic power injector (Stellant D; Medrad, Pittsburgh, PA, USA). After obtaining unenhanced CT images, portal venous phase images were acquired 60–70 seconds after administration of the contrast medium. S-CT scans were obtained in the prone position, and the scanning field ranged from the diaphragmatic dome to the anal verge. All examinations were performed during deep inspiration. Axial S-CT images were reconstructed with 5 mm section thickness and a 5 mm reconstruction interval for clinical interpretation, in addition to axial images. Coronal multiplanar reconstruction (MPR) images were reconstructed with a 3 mm section thickness at a 3 mm interval.

^{18}F-FDG PET/CT Protocol

All patients were instructed to fast for 8 hours (except for glu-

cose-free oral hydration) before the PET examination, and blood glucose concentration was measured and confirmed to be 140 mg/dL. Intravenous injections of 5.5 MBq of ^{18}F-FDG/kg body weight were administered. All patients were kept lying comfortably during the 60-minute uptake period and voided urine before being positioned supine on the scanning table. Integrated FDG PET/CT scanning was performed using a combined PET/CT scanner (Philips Gemini, 16, Best, the Netherlands). The first unenhanced CT scan with a 16 slice scanner was performed from the ear to the mid-thigh 60 minutes after the ^{18}F-FDG injection using the following parameters: 120 kVp; 250 mA; rotation time, 0.5 second; helical thickness, 5 mm; 24 mm per rotation (speed); and a 128 × 128 matrix. A PET scan was then acquired from the level of the ear through the mid-thigh in three-dimensional mode at 1 minute per bed position. The PET unit had an axial field of view of 18 cm and a spatial resolution of 4.5 mm in full width of half maximum at 1 cm from the center. PET data were reconstructed iteratively using the row action maximum likelihood algorithm. The reconstructed CT, PET, and fused PET/CT images were displayed in axial and coronal planes. The median interval between S-CT and ^{18}F-FDG PET/CT was 1 day (range, 1–22 days).

Image Analysis

Two radiologists (with 11 and 4 years experience in radiology, respectively) who were familiar with interpreting S-CT and whole body PET/CT examinations, reviewed the S-CT and ^{18}F-FDG PET/CT scans. The radiologists knew that the patients had been referred for a gastric cancer evaluation but were unaware of all other information regarding the patient's detailed medical history, laboratory results, findings from other imaging modalities, and the final diagnosis. They independently reviewed the three S-CT and ^{18}F-FDG PET/CT sets in a random order; 1) the S-CT set, 2) the ^{18}F-FDG PET/CT set, 3) the combined set, i.e., the S-CT set and ^{18}F-FDG PET/CT set. Each reading session was separated by 4 weeks to minimize recall bias. The images from each set were presented to each reader in a random order during each session. Differences in their assessments were resolved by consensus. If at least one of the two readers correctly indicated a gastric cancer lesion, it was regarded as a visible tumor. If both reviewers missed a gastric cancer lesion, it was regarded as an invisible tumor.

The stomach was divided into three segments along the longitudinal axis (from the gastroesophageal junction to the pyloric canal) of upper, middle, and lower thirds (8). If the gastric cancer was located across segments, the position of the gastric cancer was set where the lesion had the greatest involvement.

Both reviewers graded the likelihood for the presence of primary gastric cancer in 759 gastric segments based on a 4-point scale as follows: 1, definitely absent; 2, probably absent; 3, probably present; and 4, definitely present. The readers were aware that only scores of 3 and 4 would be considered gastric cancer for statistical analysis purposes. The presence of EGC was defined as mucosal enhancement with or without focal thickening in the gastric inner and/or middle layer during analysis of the preoperative S-CT scans for detecting primary tumors. Strong and focal FDG uptake combined with a delayed image was indicative of a malignant lesion during analysis of the preoperative ^{18}F-FDG PET/CT scans for detecting primary tumors, but diffuse or segmental patterns without focally increased accumulation were interpreted as physiological uptake. Strong and focal FDG uptake lesions, which were invisible on S-CT, were considered malignant lesions. All images were reviewed using a local picture archiving and communication system (GE Medical Systems, Milwaukee, WI, USA).

Statistical Analysis

All lesions, EGCs, and AGCs were analyzed separately. An alternative-free response receiver operating characteristic (ROC) curve was fitted to each reader's confidence scoring based on the retrospective interpretation. The diagnostic accuracies of the S-CT and the combined sets were determined by calculating the area under each reader-specific ROC curve (Az) (9). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for detecting gastric cancer in each of the modalities. Interobserver agreements for the confidence ratings to detect gastric cancer were analyzed with kappa statistics: < 0.40 = poor agreement; 0.41–0.74 = moderate/good agreement; and > 0.75 = excellent agreement. The McNemar test, logistic regression with the generalized estimating equation method, and the weighted least square method for repeated categorical data analysis were used to assess the statistical significance of any difference among the modalities (S-CT set, ^{18}F-FDG PET/CT set, and combined set). All statistical computations were performed

using MedCalc Software, v.12.7.8 statistical software (Mariakerke, Belgium), SAS 9.2 (SAS Institute, Cary, NC, USA), or SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). A p-value < 0.05 was considered significant.

RESULTS

Of the 267 primary gastric cancers, 22 lesions were located in the upper segment, 91 in the middle segment, and 154 in the lower segment.

Each reader noted significantly higher Az values for diagnosing all primary gastric cancers and EGCs with the combined set than those for the S-CT set. The reader's Az values were not different between the combined set and the S-CT set for detecting AGCs (Table 1, Fig. 1).

In the consensus reading, sensitivities for detecting all primary

Table 1. Area Under the Alternative-Free Response Receiver-Operating Characteristic Curve (Az) of S-CT Set and Combined Set in the Detection of Primary Gastric Cancers According to Invasiveness*

	All Lesions		EGCs		AGCs	
	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
S-CT set	0.808 ± 0.020	0.779 ± 0.021	0.710 ± 0.028	0.664 ± 0.029	0.988 ± 0.010	0.982 ± 0.012
Combined set	0.849 ± 0.018$^{\dagger 1}$	0.832 ± 0.019$^{\dagger 1}$	0.769 ± 0.026$^{\dagger 2}$	0.743 ± 0.027$^{\dagger 1}$	0.994 ± 0.007$^{\dagger 1}$	0.994 ± 0.007$^{\dagger 2}$

Note.—*Az values are mean ± standard deviation.
†Values between S-CT set and combined set were significantly different (1, p < 0.0001; 2, p = 0.0001).
‡Values between S-CT set and combined set were not significantly different (1, p = 0.6034; 2, p = 0.3546).
AGC = advanced gastric cancer, EGC = early gastric cancer, S-CT = hydro-stomach CT

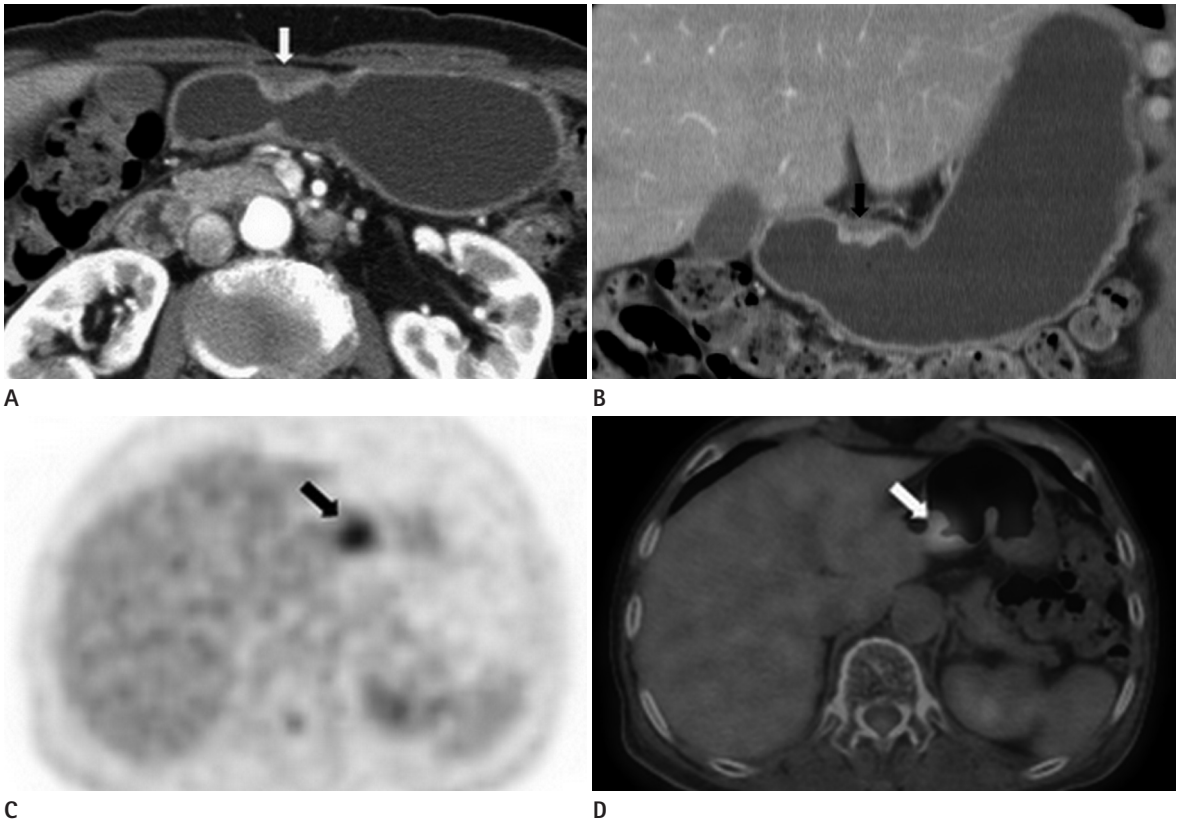

Fig. 1. A 69-year-old male with a poorly differentiated adenocarcinoma of the lesser curvature side of stomach antrum (T2 stage).
A, B. Axial and coronal CT scan show ulcerofungating with submucosal enhancing lesion (black and white arrows) in the stomach antrum.
C, D. Positron emission tomography (PET) and PET/CT fusion image show thickened stomach wall with focal strong fluorodeoxyglucose uptake lesion (black and white arrows) in the stomach antrum. The mean maximum standardized uptake values were both 4.2.

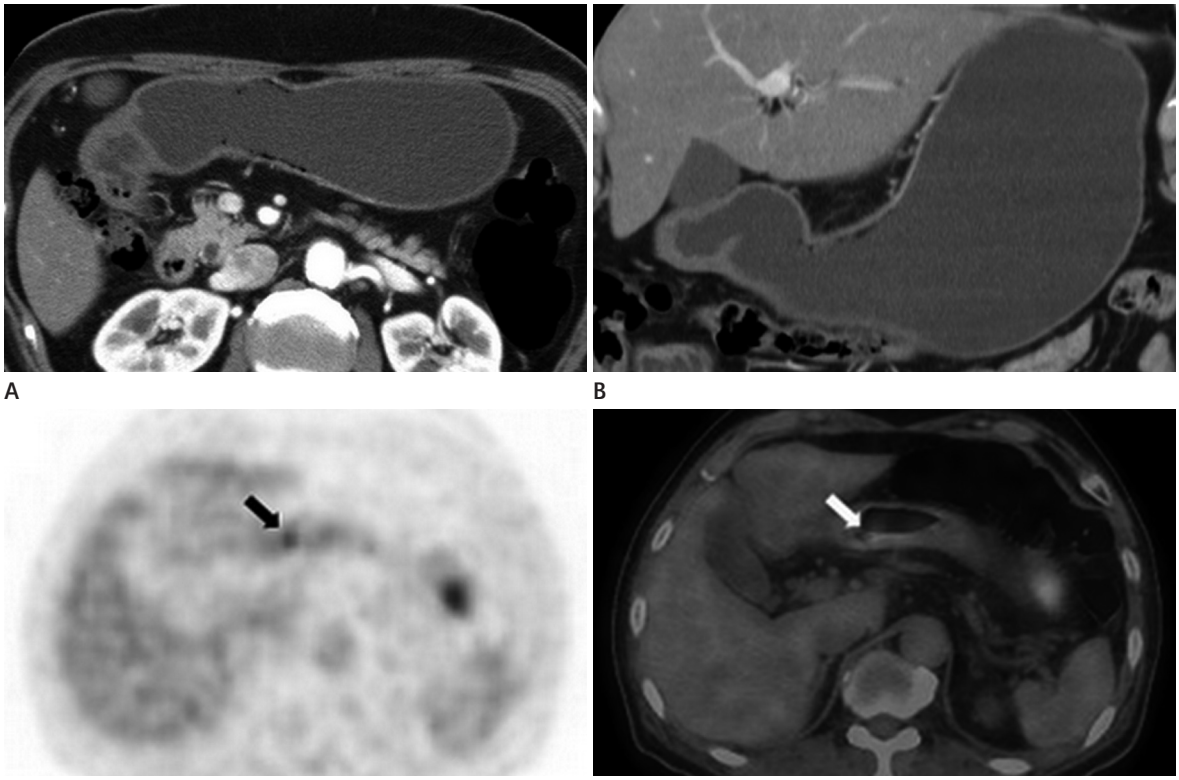

Fig. 2. A 75-year-old male with a moderately differentiated adenocarcinoma of the lesser curvature side of stomach antrum (T1a stage).
A, B. Axial and coronal CT scan show no detectable lesion in the stomach.
C, D. Positron emission tomography (PET) and PET/CT fusion image show focal fluorodeoxyglucose uptake lesion (black and white arrow) in lesser curvature side of stomach antrum. The mean maximum standardized uptake values were both 3.0.

gastric cancers and EGCs were significantly higher with the combined set (66.3% for all lesions; 50.8% for EGCs) than those with the S-CT set (61.4% for all lesions; 40.2% for EGCs) and with the ^{18}F-FDG PET/CT set (42.3% for all lesions; 27.9% for EGCs) (Fig. 2). The combined set also had significantly higher sensitivity (98.9%) than that of the ^{18}F-FDG PET/CT set (72.7%), but no significant difference was observed with the S-CT set (97.7%) for detecting AGCs (Fig. 3). Specificities were significantly higher with the ^{18}F-FDG PET/CT set (100% for all lesions and EGCs) than those with the S-CT set (98.8% for all lesions; 98.2% for EGCs) and the combined set (98.8% for all lesions; 98.2% for EGCs) for detecting all primary gastric cancers and EGCs. The PPVs for detecting all primary gastric cancers and EGCs were also significantly higher with the ^{18}F-FDG PET/CT set (100% for all lesions and EGCs) than those with the S-CT set (96.5% for all lesions; 92.3% for EGCs) and with the combined set (96.7% for all lesions; 93.8% for EGCs). In addition, the NPVs for detecting all primary gastric cancers and EGCs were significantly higher with the combined set (84.4% for all lesions; 78.7% for EGCs) than those with the S-CT set (82.5% for all lesions; 75.2% for EGCs) or the ^{18}F-FDG PET/CT set (76.2% for all lesions; 72.0% for EGCs) (Table 2).

Six false-positive lesions were noted by both readers in the S-CT set during the consensus reading. All six lesions showed mild mucosal enhancement or subtle elevated lesions on portal phase S-CT scans. These lesions were not detected on the ^{18}F-FDG PET/CT set. Endoscopic or pathological findings of these lesions suggested gastritis or non-specific lesions. However, these lesions were regarded as negative lesions on the combined set.

Interobserver agreement for detecting all lesions, EGCs, and AGCs was excellent (k = 0.764–0.914) (Table 3).

DISCUSSION

Gastric cancer is one of the most common malignant tumors of the alimentary tract. Improved early diagnosis, accurate clini-

cal staging, and optimal surgical procedures are essential to improve prognosis (10).

CT has been the modality of choice for the preoperative evaluation and staging patients with gastric cancer. However, its use for detecting gastric cancer is limited because CT has a primary tumor detection rate of 85–95% in patients with AGC (1, 11, 12)

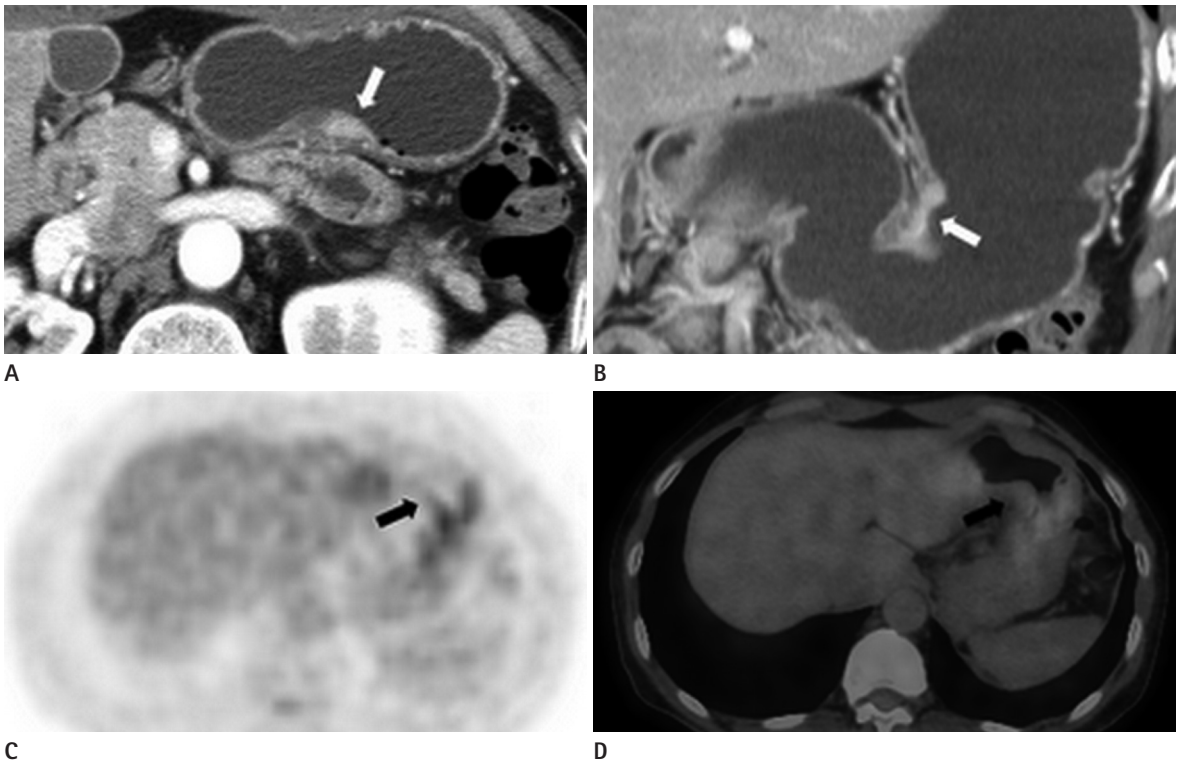

Fig. 3. A 55-year-old male with a moderately-differentiated adenocarcinoma of the posterior wall of stomach body (T3).
A, B. Axial and coronal CT scan show focal wall thickening and enhancement in the lower body of the stomach, near the angle area (white arrow).
C, D. Positron emission tomography (PET) and PET/CT fusion image obtained at the same level show no discernible fluorodeoxyglucose uptake in the stomach (black arrow).

Table 2. Diagnostic Performance of S-CT Set, ^{18}F-FDG PET/CT Set, and Combined Set According to Invasiveness in Consensus Reading*

	All Lesions			EGCs			AGCs		
	S-CT Set	^{18}F-FDG PET/CT Set	Combined Set	S-CT Set	^{18}F-FDG PET/CT Set	Combined Set	S-CT Set	^{18}F-FDG PET/CT Set	Combined Set
Sensitivity	164/267^{§1} (61.4)	113/267^{†1} (42.3)	177/267† (66.3)	72/179^{§4} (40.2)	50/179^{†1} (27.9)	91/179† (50.8)	86/88^{§1} (97.7)	64/88^{†1} (72.7)	87/88 (98.9)
Specificity	486/492^{§2} (98.8)	492/492^{†2} (100)	486/492 (98.8)	325/331^{§5} (98.2)	331/331^{†4} (100)	325/331 (98.2)	176/176 (100)	176/176 (100)	176/176 (100)
PPV	164/170^{§3} (96.5)	113/113^{†3} (100)	177/183 (96.7)	72/78^{§6} (92.3)	50/50^{†5} (100)	91/97 (93.8)	86/86 (100)	64/64 (100)	86/86 (100)
NPV	486/589^{§1} (82.5)	492/646^{†1} (76.2)	486/576† (84.4)	325/432^{§7} (75.2)	331/460^{†1} (72.0)	325/413† (78.7)	176/178^{§1} (98.9)	176/200^{†1} (88.0)	176/177 (99.4)

Note.—*Numbers are absolute values with percentages in parentheses. Values between each sets without superscript "†" or "†" or "§" mark were not available or not significantly different.
†Values between S-CT set and combined set were significantly different ($p < 0.0001$).
†Values between ^{18}F-FDG PET/CT set and combined set were significantly different (1, $p < 0.0001$; 2, $p = 0.0137$; 3, $p = 0.0126$; 4, $p = 0.0134$; 5, $p = 0.0108$).
§Values between S-CT set and ^{18}F-FDG PET/CT set were significantly different (1, $p < 0.0001$; 2, $p = 0.0137$; 3, $p = 0.0126$; 4, $p = 0.0041$; 5, $p = 0.0134$; 6, $p = 0.0108$; 7, $p = 0.0111$).
AGC = advanced gastric cancer, EGC = early gastric cancer, NPV = negative predictive value, PPV = positive predictive value, S-CT = hydro-stomach CT, ^{18}F-FDG PET/CT = ^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography

Table 3. Agreement between Readers Regarding the Confidence Level*

Imaging Sets	All Lesions	EGCs	AGCs
S-CT set	0.914	0.857	0.910
^{18}F-FDG PET/CT set	0.815	0.764	0.808

Note.—*Data are kappa values that indicate the degree of agreement between readers regarding the confidence level of lesions.
AGC = advanced gastric cancer, EGC = early gastric cancer, S-CT = hydro-stomach CT, ^{18}F-FDG PET/CT = ^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography

and plays only a limited role detecting lesions in patients with EGC. Studies in which dynamic or multiphase scanning was used to evaluate EGC achieved detection rates of 44–93.5% (1, 3, 13-16). In our study, sensitivities of 40.2% and 97.7% were observed in patients with EGC and AGC, respectively, using S-CT alone. S-CT alone was limited to detect lesions in patients with EGC.

^{18}F-FDG PET has no role in primary gastric cancer detection due to its low sensitivity, particularly in EGC (17). Our study also showed sensitivity of 27.9% in patients with EGC using ^{18}F-FDG PET/CT alone. Newly developed PET-CT technology using computer software fuses the PET metabolic-change image with a three-dimensional image of the corresponding anatomical location on the CT image, which improves diagnostic accuracy of cancer metastasis to the lymph nodes and organs distant from the tumor (10). However, the stomach was difficult to evaluate on ^{18}F-FDG PET/CT because the ^{18}F-FDG PET/CT protocol did not include expanding the stomach and used non-contrast CT. ^{18}F-FDG PET/CT and gastric distension using a mixture of milk and Diatrizoate Meglumine results in more obvious contrast between the normal stomach wall and the lesion, but it does not significantly improve diagnostic accuracy (17). Zhu et al. (18) reported that gastric cancer approximately 1.2 cm in diameter is detectable using a mixture of milk and Diatrizoate Meglumine for gastric distension on PET/CT imaging. Kamimura et al. (19) reported that the accuracy of cancer diagnosis increases by having the patient drink water to increase gastric volume prior to ^{18}F-FDG PET. However, any potential improvement in PET/CT diagnostic accuracy for gastric cancer using negative oral contrast agents compared to positive oral contrast agents needs to be further evaluated.

In this study, 253 patients were subjected to a qualitative diagnosis of primary gastric cancer using a combination of S-CT and ^{18}F-FDG PET/CT. Overall sensitivities showed that the combined set of S-CT and ^{18}F-FDG PET/CT provided significantly higher sensitivities for detecting all primary gastric cancers and EGCs than those of S-CT and ^{18}F-FDG PET/CT alone. Because EGC can only be detected by either S-CT or ^{18}F-FDG PET/CT, the combined set resulted in a significantly higher detection rate than that of S-CT or ^{18}F-FDG PET/CT alone. For example, linitis platisca of the stomach, in which gastric endoscopy is normal, can be detected by ^{18}F-FDG PET/CT (20). In addition, the combined set also had a significantly higher NPV for detecting all primary gastric cancers and EGCs compared to that of S-CT and ^{18}F-FDG PET/CT alone but was not different for detecting AGCs.

The combined S-CT and ^{18}F-FDG PET/CT set had the following advantages. First, gastric cancer lesions often obscured by physiological uptake on ^{18}F-FDG PET/CT can be identified on S-CT, which provides detailed anatomical information. Second, if EGCs, which have a low detection rate on S-CT, are identified on ^{18}F-FDG PET/CT, it is possible to review the S-CT backwards to find the primary cancer. Although sensitivities for detecting all primary gastric cancers and EGCs with the combined set were 66.3% and 50.8% respectively, it was valuable to add ^{18}F-FDG PET/CT to S-CT to detect and localize primary gastric cancer.

This study had some limitations. First, this study was a retrospective, single institution study over a defined period. Second, we did not include CT gastrography, which is helpful for detecting primary gastric cancer (3). Therefore, a further comparative study is needed using S-CT and CT gastrography to detect primary gastric cancer. Third, this study was conducted in a highly selected patient population with primary gastric cancer diagnosed by endoscopic biopsy. Thus, it was unclear to what degree the current findings can be generalized to a wider population. Fourth, arterial phase images were not obtained. We obtained images in the portal venous phase (70 seconds). Lee et al. (16) reported that helical CT with a two-phase scan including the mucosal phase is efficient for identifying EGC enhancement patterns. However, it is controversial whether there is added value of arterial phase imaging to reveal gastric cancer on CT. Fifth, axial S-CT images were reconstructed with 5-mm section thick-

ness and a reconstruction interval. Choi et al. (21) reported that axial CT images used for preoperative gastric cancer staging should be reconstructed using 3-mm section thickness and a 2–3 mm reconstruction interval. Coronal and sagittal MPR images are also reconstructed with a 3-mm section thickness and interval. However, other reports used a 5-mm section thickness for axial CT images (3, 8), whereas we included coronal MPR images with a 3-mm section thickness for detecting gastric cancer. Sixth, ^{18}F-FDG PET/CT was performed without gastric distension. ^{18}F-FDG PET/CT with gastric distension using a negative or positive oral contrast agent increases the detection rate of primary gastric cancer.

In conclusion, detecting primary gastric cancer for localization and staging is very important, and our results show that the combined S-CT and ^{18}F-FDG PET/CT set provided a significantly higher detection rate for primary gastric cancer than that of S-CT or ^{18}F-FDG PET/CT alone, particularly for EGCs. Higher diagnostic accuracies were obtained with a combined set than that with S-CT alone. Therefore, combined reading of S-CT and ^{18}F-FDG PET/CT is recommended to ensure better detection during preoperative evaluations for primary gastric cancer.

REFERENCES

1. Shen Y, Kang HK, Jeong YY, Heo SH, Han SM, Chen K, et al. Evaluation of early gastric cancer at multidetector CT with multiplanar reformation and virtual endoscopy. *Radiographics* 2011;31:189-199
2. Sim SH, Kim YJ, Oh DY, Lee SH, Kim DW, Kang WJ, et al. The role of PET/CT in detection of gastric cancer recurrence. *BMC Cancer* 2009;9:73
3. Chen CY, Hsu JS, Wu DC, Kang WY, Hsieh JS, Jaw TS, et al. Gastric cancer: preoperative local staging with 3D multidetector row CT--correlation with surgical and histopathologic results. *Radiology* 2007;242:472-482
4. Hwang SW, Lee DH, Lee SH, Park YS, Hwang JH, Kim JW, et al. Preoperative staging of gastric cancer by endoscopic ultrasonography and multidetector-row computed tomography. *J Gastroenterol Hepatol* 2010;25:512-518
5. Lim JS, Yun MJ, Kim MJ, Hyung WJ, Park MS, Choi JY, et al. CT and PET in stomach cancer: preoperative staging and monitoring of response to therapy. *Radiographics* 2006; 26:143-156
6. Yun M. Role of F-18 FDG PET or PET/CT in the evaluation of gastric cancer. *Nucl Med Mol Imaging* 2006;40:141-147
7. Washington K. 7th edition of the AJCC cancer staging manual: stomach. *Ann Surg Oncol* 2010;17:3077-3079
8. Park KJ, Lee MW, Koo JH, Park Y, Kim H, Choi D, et al. Detection of early gastric cancer using hydro-stomach CT: blinded vs unblinded analysis. *World J Gastroenterol* 2011;17: 1051-1057
9. Chung WS, Kim MJ, Chung YE, Kim YE, Park MS, Choi JY, et al. Comparison of gadoxetic acid-enhanced dynamic imaging and diffusion-weighted imaging for the preoperative evaluation of colorectal liver metastases. *J Magn Reson Imaging* 2011;34:345-353
10. Li B, Zheng P, Zhu Q, Lin J. Accurate preoperative staging of gastric cancer with combined endoscopic ultrasonography and PET-CT. *Tohoku J Exp Med* 2012;228:9-16
11. Hori S, Tsuda K, Murayama S, Matsushita M, Yukawa K, Kozuka T. CT of gastric carcinoma: preliminary results with a new scanning technique. *Radiographics* 1992;12:257-268
12. Mani NB, Suri S, Gupta S, Wig JD. Two-phase dynamic contrast-enhanced computed tomography with water-filling method for staging of gastric carcinoma. *Clin Imaging* 2001;25:38-43
13. Tsuda K, Hori S, Murakami T, Nakamura H, Tomoda K, Nakanishi K, et al. Intramural invasion of gastric cancer: evaluation by CT with water-filling method. *J Comput Assist Tomogr* 1995;19:941-947
14. Cho JS, Kim JK, Rho SM, Lee HY, Jeong HY, Lee CS. Preoperative assessment of gastric carcinoma: value of two-phase dynamic CT with mechanical iv. injection of contrast material. *AJR Am J Roentgenol* 1994;163:69-75
15. Fukuya T, Honda H, Kaneko K, Kuroiwa T, Yoshimitsu K, Irie H, et al. Efficacy of helical CT in T-staging of gastric cancer. *J Comput Assist Tomogr* 1997;21:73-81
16. Lee JH, Jeong YK, Kim DH, Go BK, Woo YJ, Ham SY, et al. Two-phase helical CT for detection of early gastric carcinoma: importance of the mucosal phase for analysis of the abnormal mucosal layer. *J Comput Assist Tomogr* 2000;24:777-782

17. Ma Q, Xin J, Zhao Z, Guo Q, Yu S, Xu W, et al. Value of ^{18}F-FDG PET/CT in the diagnosis of primary gastric cancer via stomach distension. *Eur J Radiol* 2013;82:e302-e306
18. Zhu Z, Li F, Mao Y, Cheng W, Cheng X, Dang Y. Improving evaluation of primary gastric malignancies by distending the stomach with milk immediately before 18F-FDG PET scanning. *J Nucl Med Technol* 2008;36:25-29
19. Kamimura K, Nagamachi S, Wakamatsu H, Fujita S, Nishii R, Umemura Y, et al. Role of gastric distention with additional water in differentiating locally advanced gastric carcinomas from physiological uptake in the stomach on 18F-fluoro-2-deoxy-D-glucose PET. *Nucl Med Commun* 2009;30:431-439
20. Harisankar CN, Kashyap R, Bhattacharya A, Mittal BR. Fluoro-deoxy-glucose positron emission tomography/computed tomography pattern in a patient with linitis plastica of the stomach caused by primary signet cell adenocarcinoma. *World J Nucl Med* 2012;11:26-27
21. Choi JI, Joo I, Lee JM. State-of-the-art preoperative staging of gastric cancer by MDCT and magnetic resonance imaging. *World J Gastroenterol* 2014;20:4546-4557

위암의 원발 병소 발견에서 ^{18}F–Fluorodeoxyglucose 양전자전산화단층촬영, 위장전산화단층촬영, 병용 검사의 유용성 비교[1]

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목적: 위암의 원발 병소 발견에서 ^{18}F-fluorodeoxyglucose 양전자전산화단층촬영(positron emission tomography/computed tomography; 이하 PET/CT)과 위장전산화단층촬영(hydro-stomach CT; 이하 S-CT), 그리고 이 두 검사를 병용하였을 때의 유용성에 대해 알아보았다.

대상과 방법: 위암으로 수술 전 PET/CT와 S-CT를 시행받은 253명의 환자를 대상으로 후향적으로 연구를 시행하였다. 2명의 영상의학과 의사가 독립적으로 PET/CT 세트와 S-CT 세트, 그리고 이들의 병용세트를 이용하여 국소 종양의 유무를 4점 척도로 판정하였다. 진단의 정확도는 receiver operating characteristic 곡선하 면적을 이용하여 평가하였고, 민감도, 특이도, 양성예측도, 음성예측도를 측정하였다.

결과: 총 253명의 환자, 267병소에서 조직학적으로 179개의 조기위암과 88개의 진행성 위암이 진단되었다. 병용세트는 모든 원발성 위암과 조기 위암의 발견에서 진단의 정확도, 민감도, 음성예측도가 PET/CT 세트 또는 S-CT 세트 단독보다 통계적으로 유의하게 높았다. 또한 병용 세트는 진행성 위암의 발견에 있어 PET/CT 세트보다 민감도와 음성예측도가 통계적으로 유의하게 높았으나 S-CT 세트와는 통계적 유의성이 없었다. PET/CT 세트는 모든 원발성 위암과 조기 위암군의 환자에서 특이도와 양성예측도가 병용 세트 또는 S-CT 단독보다 통계적으로 유의하게 높았다.

결론: PET/CT와 S-CT의 병용은 S-CT 단독보다 진단의 정확도가 높았으며 특히 조기 위암의 발견에 의의가 있었다.

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